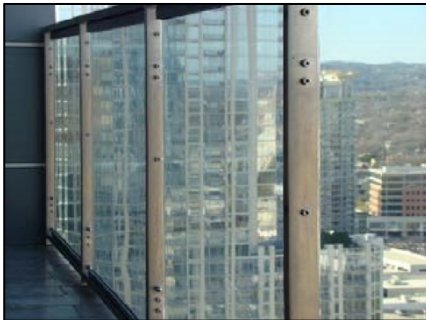


## Use of Laminated Glass in Glass Railing Systems



### Introduction

Glass railing systems are used in a variety of residential and commercial settings for safety and the beauty glass adds to a structure. Laminated glass is the ideal glazing material for this application and offers a variety of design options. The interlayer can be clear, tinted, or custom printed. The glass can be clear, tinted or decorative; flat or curved; fully supported on 1, 2, 3, or 4 edges; or minimally supported with bolts and/or clamps. Laminated glass offers a benefit over monolithic tempered glass when used in railings; if breakage occurs, glass particles tend to adhere to the laminate interlayer increasing the likelihood of glass retention in the system.

Interior glass railings create an open feeling on the inside of a large space and enhance visibility and daylighting. These railing systems may be used in spaces such as, but not limited to, shopping centers, hotels, office buildings, restaurants and hospitals. Laminated glass railing systems can also be installed in exterior applications, such as balconies in apartments, hotels, and condominiums. Laminated glass provides improved resistance to glass fallout in the event of breakage. If the laminate edge is not covered, additional consideration should be given to the interlayer type and glazing system design.

Laminated glass railing systems provide a clear barrier in many sports venues around the world. While a top rail is still required by code, in some instances the metal top cap and handrail have been eliminated, with approval of the building official, to afford spectators an unobstructed view onto the playing field. This is discussed in further detail in the Building Code Requirements section below with regards to code adherence.

## Definitions

*Handrail:* According to the IBC 2015, a horizontal or sloping rail intended for grasping by the hand for guidance or support.

*Guardrail:* According to ASTM E2353 Section 3.2.3, a protective railing system around the outer edges of locations of an accessible roof, balcony, landing, platform or ramp designed to minimize the probability of an accidental fall from the walking surface.

*Guard:* According to the IBC 2015, a building component or system of building components located at or near the open sides of elevated walking surfaces that minimizes the possibility of a fall from the walking surface to a lower level.

*Baluster:* a vertical support piece, such as a lite of glass.

*Balustrade:* a railing supported by balusters.

*Infill Panel:* the material that occupies the space between supporting structural members of the system, and functions as the guard in the system.

## Glass Selection

ASTM C1172 *Standard Specification for Laminated Architectural Flat Glass* is the industry specification for laminated glass. ASTM C1048 - *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass* is the industry specification for heat-strengthened and tempered glass. ASTM C1048 also contains vital information about the fabrication of holes and/or notches.

Additionally, two ASTM standards and one Canadian Standards Association (CSA) standard address testing, specification, and design of glass railings. These are:

- ASTM E2353 *Standard Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades*
- ASTM E2358 *Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades*
- CSA A500 *Guard Standard*

## Building Code Requirements

The 2015 International Building Code (IBC) makes specific reference to glass railings in Section 2407 of the code. The code requires the use of laminated glass with very few exceptions.

The main points of section 2407 of the 2015 IBC are:

1. Laminated glass must be used in handrails, guardrails or guards.
2. Glass types must be fully tempered laminated or heat-strengthened laminated.
3. Laminate must comply with CPSC 16 CFR 1201 Cat II or ANSI Z97.1-2015 Class A
4. Minimum nominal thickness must be 1/4 in.
5. Single fully tempered glass is permitted where there is no walking surface beneath the system or where the surface is permanently protected from the risk of falling glass.
6. Handrail or guard section must be supported by a minimum of three glass balusters, or shall be otherwise supported to remain in place should one baluster panel fail.
7. The panels and their support systems should be designed to withstand the loads as specified by the code. A design factor of 4 must be used in designing the glass.\*

8. Top rail is not required if the laminated glass is comprised of two or more glass lites having equal thickness and only then if the system receives approval from the building official.
9. In windborne debris regions, in-fill glass and glass balusters must be laminated and comply with safety glazing standards.
10. In windborne debris regions, if the glass is supporting a top rail, the top rail must stay in place after impact testing.
11. Glazing materials may not be installed as handrails or guards in parking garages except in pedestrian areas.

The 2015 IBC represents a major change in the use of glass in railing systems. Prior to the 2015 code, the designer could use either monolithic tempered or laminated glass in most railing applications. As states adopt the 2015 IBC, the use of monolithic tempered glass will be restricted, and will be replaced by a heat-strengthened or tempered laminated glass alternative. The adoption process is often slow at the state level. Since older versions of the code may govern the code approval process, designers and specifier are advised to consider the risks associated with glass breakage and specify laminated glass to conform to best industry practices.

*\*The design factor is used to reduce a material's limiting stress to an allowable stress in design.*

**Glass Railing Performance Standards (derived from ASTM E2358)**

Glass railing system testing is done according to ASTM E2353 *Standard Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards & Balustrades*. The standard evaluates static strength, impact resistance, and post-break retention. Railing systems are specified according to ASTM E2358, *Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades*. These systems include glazing infill, as well as structural glass railing types. The four levels of performance are shown in Table 1. Post-impact classifications per ASTM E2358 are shown below.

**TABLE 1 Performance Requirements**

System Type	Performance Level (Indicator)	Structural Performance <sup>A</sup>	Safety Impact Performance <sup>B</sup>	Enhanced Impact Performance <sup>C</sup>
I - V	Level 1 (Type-L1)	Concentrated load: 890 N (200 lbf) Uniform Load: 290 N/m (20 lbf/ft) Infill Horizontal Load: 220 N (50lbf) <sup>D</sup>	Pass 203 J 150 ft ·lb	Not Required
I - V	Level 2 (Type-L2)	Concentrated load: 890 N (200 lbf) Uniform Load: 730 N/m (50 lbf/ft) Infill Horizontal Load: 220 N (50lbf) <sup>D</sup>	Pass 542 J 400 ft ·lb	Not Required
I - V	Level 3 (Type-L3)	Concentrated load: 1330 N (300 lbf) Uniform Load: 730 N/m (50 lbf/ft) Infill Horizontal Load: 220 N (50lbf) <sup>D</sup>	Pass 542 J 400 ft ·lb	Pass
I - V	Level 4 (Type-L4)	Concentrated load: 1620 N (365 lbf) Uniform Load: 880 N/m (60 lbf/ft) Infill Horizontal Load: 220 N (50lbf) <sup>D</sup>	Pass 542 J 400 ft ·lb	Pass

<sup>A</sup>Tests performed as outlined in ASTM E935

<sup>B</sup>Tests performed as described in ANSI Z97.1 and section 13.3 of Test Method E2353.

<sup>C</sup>Tests performed as described in ASTM E2025 and section 13.4 of Test Method E2353.

<sup>D</sup>Horizontal load applied to glazing infill (Test Method C of Test Method E935) shall be distributed evenly over a 7740 mm<sup>2</sup> (12 in<sup>2</sup>) area located at the most critical point of the glazing.

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Post-impact classifications of laminated glass railings from ASTM E2353 are shown below. It is anticipated that future model building code changes will take into account the post-impact classification as a way of avoiding the requirement to get building official approval mentioned in point 8 above. A post-impact classification of 1 or 2 must be met to prevent falling glass as well as to increase protection of building occupants above ground level from falling through an unprotected opening. For Classification 2, the load that must be retained after breakage has yet to be determined.

### **Post-Impact Classification**

- 1 - Glazing unbroken
- 2 - Glazing broken and retained
- 3 - Glazing broken and not retained

### **Laminated Glass Quality**

Unlike monolithic tempered glass, edge quality with laminated glass must be clearly specified to the glass fabricator. Issues such as edge misalignment and protruding interlayer may impact the aesthetics and safety of the glass edge.

ASTM C1172 Section 8.5.1 shows standard tolerances for laminated glass including misalignment. Tighter tolerances may be required for exposed edge applications. This concern is addressed in Section 8.5.3 where it states, "For some laminated applications such as point supported glass and balustrades, where the edges of the laminate are exposed, tighter length and width tolerances may be requested by the customer. Consult the supplier to determine their capabilities."

### **Glazing System Considerations**

When a system is wet glazed, it is important to verify compatibility of the caulk, grout, blocks, and sealant used in contact with the laminate interlayer. This is especially important in exterior applications where moisture and expansion rates can impact the system. Traditional methods of setting monolithic glass in railings such as cement-based grouts may be incompatible with laminated glass. Polyurethane or epoxy type sealants may be suitable alternatives. Dry-glaze methods have shown to be compatible with laminated glass systems. Bolted or clamped systems must be designed and installed properly to avoid over-stressing the glass around the points of contact. Consult with the fabricator and component suppliers (i.e. interlayer manufacturers, sealant suppliers, etc.) for questions surrounding compatibility.

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